CHAPTER 9

PRACTICE EXERCISES

SECTION I MULTIPLE CHOICE

Questions 1 and 2

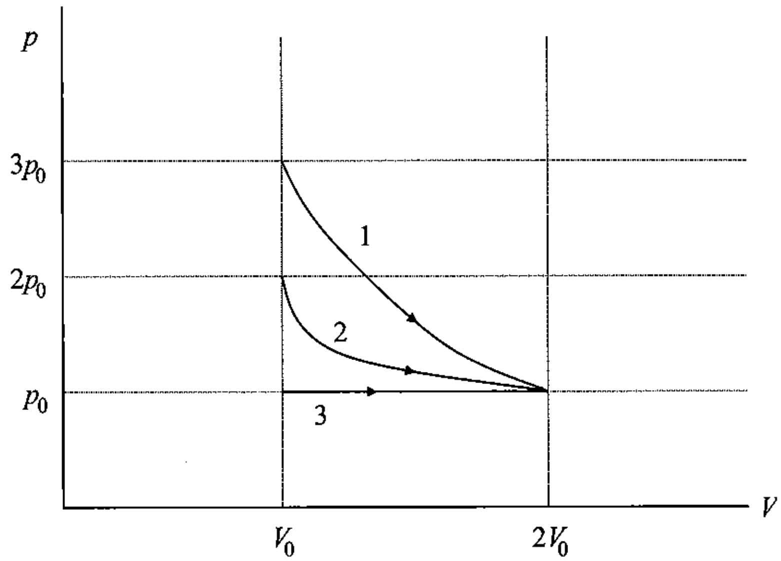

Figure 14

1. 1 mole of ideal gas is brought to a final state F by one of three processes that have different initial states as shown in the figure. What is true for the temperature change between initial and final states?

   (A) It's the same for all processes.
   (B) It's smallest for process 1.
   (C) It's smallest for process 2.
   (D) It's smallest for process 3.
   (E) It's the same for processes 1 and 2.

2. What is true for the work done by the gas?

   (A) It's positive for processes 1 and 2, but negative for process 3.
   (B) It's smallest for process 1.
   (C) It's smallest for process 2.
   (D) It's smallest for process 3.
   (E) Zero work is done along process 3.

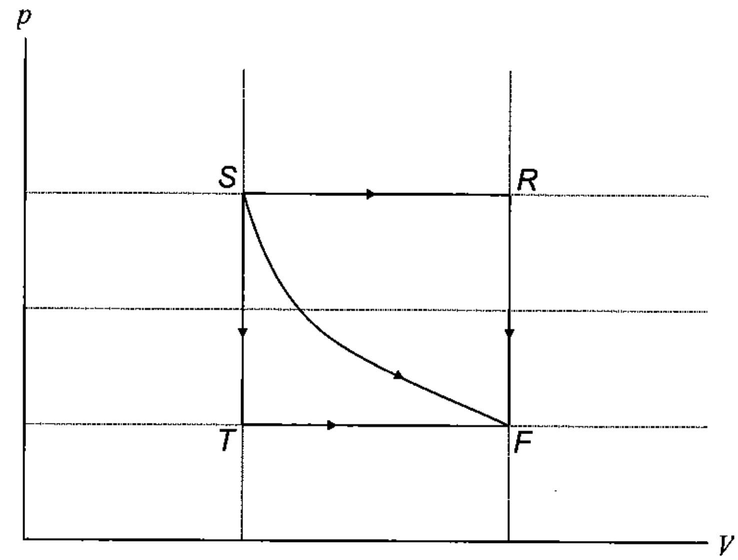

Figure 15

3. An ideal gas is brought from $S \to F$ by three different paths: *SRF*, *SF*, *STF*. The temperature at *S* is the same as the temperature at *F*. Which of the following is true?

   (A) Process *SRF* occurs at constant temperature.
   (B) The work done by the gas along *SRF* is the same as the work done by the gas along *STF*.
   (C) Net heat into the gas along *STF* is greater than the work done by the gas along this path.
   (D) The change in the internal energy is the same for all three paths.
   (E) Work done by the gas along *STF* is greater than the work done by the gas along *SF*.

Questions 4 and 5

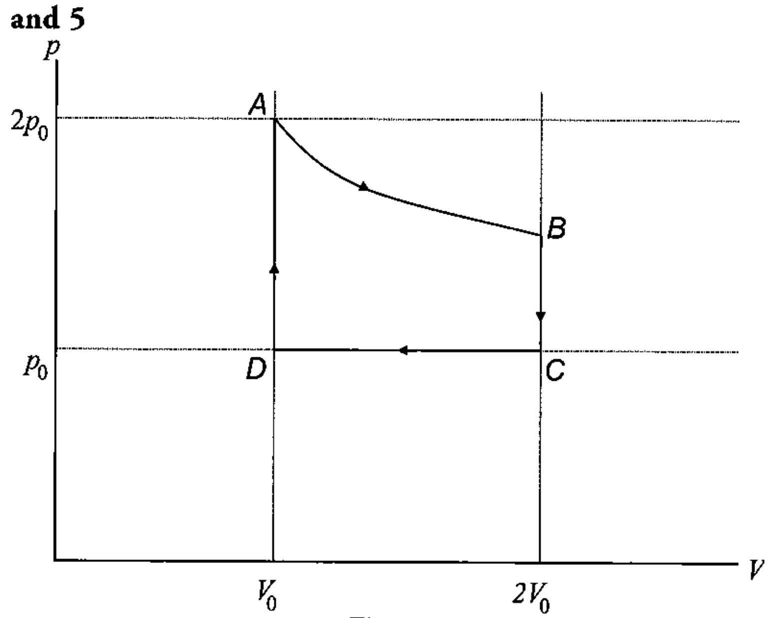

Figure 16

4. What is true for the process $D \rightarrow A$?

(A) $\Delta U = 0$ $Q > 0$
(B) $\Delta U = 0$ $Q < 0$
(C) $W = 0$ $\Delta U > 0$
(D) $W = 0$ $\Delta U < 0$
(E) $W = 0$ $Q = 0$

5. What is true for the two-step process $A \rightarrow B \rightarrow C$?

(A) $\Delta U = 0$ $Q = 0$
(B) $\Delta U = 0$ $Q > 0$
(C) $W = 0$ $Q > 0$
(D) $W = 0$ $Q < 0$
(E) $W > 0$ $Q < 0$

6. 200 J enters a Carnot engine from the hot reservoir, held at 400 K. During the entire cycle, 50 J of useful work is performed by the engine. What is the temperature of the cold reservoir?

(A) 100 K
(B) 200 K
(C) 300 K
(D) 250 K
(E) 150 K

7. For an ideal gas in a container with fixed volume and constant temperature, which of the following is true?
I. Pressure results from molecular collisions with the walls.
II. The molecules all have the same speed.
III. The average kinetic energy is directly proportional to the temperature.

(A) I, II, and III
(B) I and II only
(C) II and III only
(D) II only
(E) I and III only

8. 1 mole of ideal gas is in a container of volume V, temperature T, and pressure p. If the volume is halved and the temperature is doubled, the pressure will be

(A) p
(B) $2p$
(C) $4p$
(D) $\frac{1}{2}p$
(E) $\frac{1}{4}p$

9. Two identical containers contain 1 mole each of two different monatomic ideal gases, gas A and gas B, with the mass of gas B 4 times the mass of gas A. Both gases are at the same temperature. 10 J of heat is added to gas A, resulting in a temperature change ΔT. How much heat must be added to gas B to cause the same ΔT?

(A) 10 J
(B) 100 J
(C) 40 J
(D) 2.5 J
(E) 1,600 J

10. The entropy of a closed macroscopic system will never decrease because

(A) energy wouldn't be conserved if entropy decreased
(B) for large systems, the probability of such a decrease is negligible
(C) mechanical equilibrium couldn't be sustained with a decrease in entropy
(D) heat can never be made to flow from a cold object to a hot object
(E) molecular motions reach their minimum only at absolute 0

11. During a certain process, 600 J of heat is added to a system. While this occurs, the system performs 200 J of work on the surroundings. The change in internal energy of the system is

(A) 200 J
(B) 800 J
(C) 400 J
(D) −400 J
(E) impossible to determine without knowing the temperature

12. Which of the following is *not* true about thermal radiation?

(A) It's a mechanism of energy exchange between systems at different temperatures.
(B) It involves atomic excitations.
(C) Ice at 0° C will emit thermal radiation.
(D) It requires some material substance to travel through.
(E) It's a byproduct of the food we eat.

CHAPTER 9

PRACTICE EXERCISES

SECTION II FREE RESPONSE

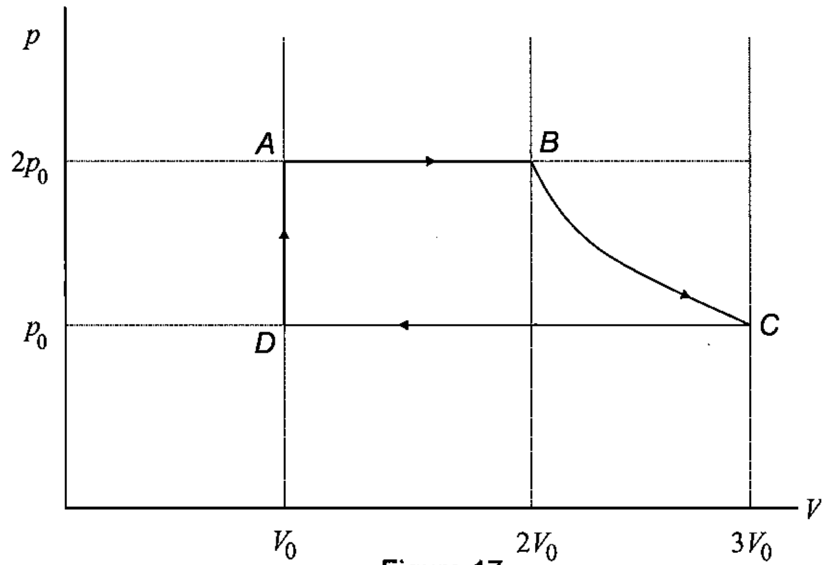

Figure 17

1. 1 mole of monatomic ideal gas is brought through a cycle $A \rightarrow B \rightarrow C \rightarrow D \rightarrow A$ as depicted above. All processes are performed slowly. Respond to the following in terms of p_0, V_0, and R.
   (a) Find the temperature at each vertex.
   (b) Find the heat added to the gas for the process $A \rightarrow B$.
   (c) Find the work done on the gas for the process $C \rightarrow D$.
   (d) Find the heat added to the gas for the process $D \rightarrow A$.
   (e) Find the change in internal energy for
      (i) process $B \rightarrow C$
      (ii) the entire cycle

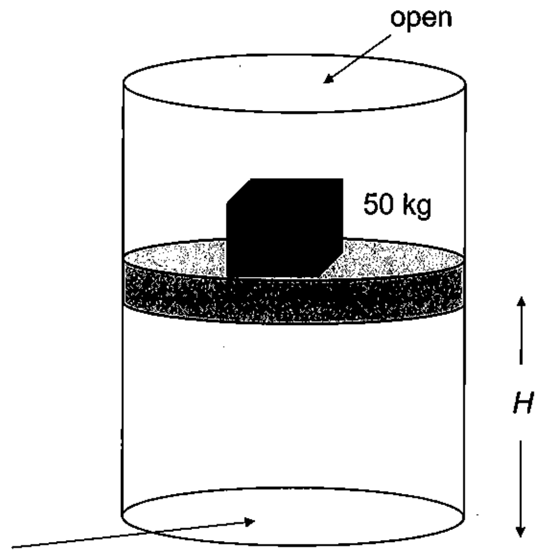

Figure 18

2. 2 moles of ideal gas are in a cylindrical container with cross-sectional area 1×10^{-2} m^3. The cylinder is fitted with a light, movable piston that's open to the atmosphere, where the pressure is 1×10^5 Pa. A 50 kg mass placed on the piston keeps it in mechanical equilibrium when the temperature is 300 K.
   (a) Find the pressure of the gas.
   (b) Find the height H of the piston.
   (c) The temperature is now reduced to 250 K.
      (i) Find the pressure.
      (ii) Find the new height H of the piston.
   (d) After the temperature change, what was the change in the internal energy of the gas?

Answers and Explanations

MULTIPLE CHOICE

1. The answer is C. The temperature for the gas at any point will be $T = \frac{pV}{R}$. Since all three processes end at the same temperature, $\frac{p(2V_0)}{R}$, the smallest change will be for the one that starts closest to this value. Process 2 actually begins at this temperature, so its change is 0.

2. The answer is D. The work done by the gas is equal to the area under the pV curve. This is different for all three processes and smallest for process 3.

3. The answer is D. The internal energy of an ideal gas depends only on temperature. If final and initial temperatures are the same, there's no change in internal energy. Since $\Delta U = 0$ for all three paths, $W = -Q$ for each process, which eliminates C. Area considerations eliminate B and E, and the fact that the temperature at R is greater than that at S (gas law) eliminates A.

4. The answer is C. There is no work since the volume doesn't change and the temperature increases (gas law), so the internal energy also increases.

5. The answer is B. The gas law gives you the same temperature at A and C, so $\Delta U = 0$. The work done on the gas is negative (the gas does positive work in expanding), so the first law says $Q > 0$.

6. The answer is C. $e = \frac{W_{by}}{Q_H} = \frac{50}{200} = 0.25$ from the definition of efficiency. Since this is a Carnot engine, $0.25 = 1 - \frac{T_C}{400} \Rightarrow T_C = 300$ K.

7. The answer is E. There is a distribution of speeds among the molecules, leading to an average value, but the molecules certainly do not all have the same speed.

8. The answer is C. The gas law gives you $\frac{pV}{T} = \frac{p'V'}{T'} \Rightarrow p' = p\frac{V}{V'}\frac{T'}{T} = 4p$.

9. The answer is A. $\Delta U = \frac{3}{2}nR\Delta T$. For the same number of moles, ΔT depends only on the energy added, not the masses of the gas molecules.

10. The answer is B. A macroscopic closed system will never decrease in entropy because the probability of such a macrostate occurring is essentially 0.

11. The answer is C. Be careful of the signs. In the first law statement, $\Delta U = Q + W$, both Q and W are positive for work done *on* the system. In this problem, $Q = +600$ J but $W = -200$ J, because it is the work done *by* the system.

12. The answer is D. Electromagnetic radiation doesn't need a material medium for transit. In E, we eat to maintain body temperature, and we emit a lot of energy as thermal radiation, derived from our food energy intake. In C, ice is cold by human standards of sensation, but it still radiates.

FREE RESPONSE

1. (a) The gas law gives you at any point: $T = \frac{pV}{R}$. This means that $T_A = \frac{2p_0V_0}{R}$,

$$T_B = \frac{4p_0V_0}{R},\ T_C = \frac{3p_0V_0}{R},\ T_D = \frac{p_0V_0}{R}.$$

(b) $A \rightarrow B$ occurs at constant pressure. We can use the first law to find Q since we can calculate ΔU from the temperature differences and we can get the work done on the gas from the area under the graph for that part of the cycle.

$$\Delta U = Q + W \Rightarrow Q = \Delta U - W = \frac{3}{2}nR\Delta T - W = \frac{3}{2}nR(T_B - T_A) - W$$

$$Q = \frac{3}{2}R\left(\frac{4p_0V_0}{R} - \frac{2p_0V_0}{R}\right) + 2p_0V_0 = 5p_0V_0$$

(c) The area under the $D \rightarrow C$ graph is $2p_0V_0$. The decrease in volume corresponds to positive work done on the gas.

(d) $D \rightarrow A$ is a constant volume process, so no work is done. Use the first law to find Q.

$$\Delta U = Q = \frac{3}{2}nR\Delta T = \frac{3}{2}R\left(\frac{p_0V_0}{R}\right) = \frac{3}{2}p_0V_0.$$

(e) i) For $B \rightarrow C$, $\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}R\left(-\frac{p_0V_0}{R}\right) = -\frac{3}{2}p_0V_0.$

ii) For the entire cycle, you end up back in the same state, so $\Delta U = 0$.

2. (a) The gas pressure will be the sum of the atmospheric pressure and the pressure exerted by the weight sitting on the piston:

$$p = 1 \times 10^5 + \frac{50(10)}{1 \times 10^{-2}} = 1.5 \times 10^5 \text{ Pa}$$

(b) The gas law gives you $V = \frac{nRT}{p} = \frac{2(8.31)(300)}{1.5 \times 10^5} = (1 \times 10^{-2})H \Rightarrow H = 3.3$ m

(c) i) The condition for mechanical equilibrium doesn't depend on temperature, so the pressure stays the same.

ii) The number of moles, pressure, and cross sections stays the same, so the gas law gives you

$$\frac{H}{T} = \frac{H'}{T'} \Rightarrow 3.3\,\frac{250}{300} = 2.75 \text{ m}$$

(d) $\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}(2)(8.31)(250-300) = -1{,}247$ J